US009483041B2

(12) **United States Patent**
Kito et al.

(10) **Patent No.:** US 9,483,041 B2
(45) **Date of Patent:** Nov. 1, 2016

(54) **BLOCK EXECUTION SEQUENCE DISPLAY SYSTEM**

(75) Inventors: **Koji Kito**, Toyota (JP); **Terukazu Senda**, Obu (JP)

(73) Assignee: **JTEKT CORPORATION**, Osaka-shi (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 742 days.

(21) Appl. No.: **13/491,919**

(22) Filed: **Jun. 8, 2012**

(65) **Prior Publication Data**

US 2013/0006391 A1   Jan. 3, 2013

(30) **Foreign Application Priority Data**

Jun. 29, 2011   (JP) 2011-144523

(51) **Int. Cl.**
   G05B 19/05   (2006.01)
   G05B 19/409   (2006.01)
(52) **U.S. Cl.**
   CPC *G05B 19/058* (2013.01); *G05B 19/409* (2013.01)
(58) **Field of Classification Search**
   CPC .. G05B 19/058; G05B 19/18; G05B 19/406; G05B 19/4063; G05B 19/4068; G05B 19/408; G05B 19/409; G05B 19/4093; G05B 19/4097; G05B 19/4099
   USPC 700/11, 17, 18, 83, 159, 247, 264
   See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,426,730 A   6/1995 Miyake et al.
5,485,620 A * 1/1996 Sadre G05B 19/41865
                                                    700/18

5,608,641 A * 3/1997 Guhl et al. 700/185
6,290,403 B1 * 9/2001 Onishi G05B 19/0426
                                                    712/200
6,859,898 B1 * 2/2005 Yamashita et al. 714/55
7,089,531 B2 * 8/2006 Rutkowski 717/113
2002/0046397 A1   4/2002 Schmitt et al.
2002/0054098 A1   5/2002 Schmitt et al.

(Continued)

FOREIGN PATENT DOCUMENTS

JP   2001-5504 A   1/2001
WO   WO 95/23374 A1   8/1995

OTHER PUBLICATIONS

Allen- Bradley Classic 1785 PLC-5 Programmable Controllers User Manual, pp. 72-77 (Chapter 6), Apr. 1996 http://literature. rockwellautomation.com/idc/groups/literature/documents/um/ 1785-um001_-en-p.pdf.*

(Continued)

Primary Examiner — Nathan L Laughlin
(74) *Attorney, Agent, or Firm* — Oblon, McClelland, Maier & Neustadt, L.L.P.

(57)   **ABSTRACT**

A block execution sequence display system includes: a machine tool that has numerical control and sequence control; a programmable controller that executes a sequence program; a numerical control device that executes a NC program; block execution sequence array display means for displaying a block execution sequence array in which sequence functional blocks and a NC program execution block are arranged in an execution sequence; selecting means for selecting one of blocks in the array; and NC functional block execution sequence array display means for, when the NC program execution block is selected by the selecting means, displaying a NC functional block execution sequence array in which a plurality of NC functional blocks are arranged in an execution sequence.

5 Claims, 5 Drawing Sheets
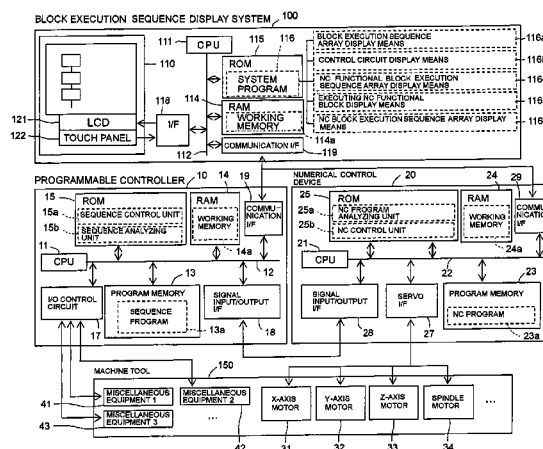
(56) **References Cited**

U.S. PATENT DOCUMENTS

2002/0054099 A1   5/2002 Schmitt et al.
2005/0027377 A1*   2/2005 Lucas G05B 19/41845
                                                                  700/28
2009/0326680 A1*   12/2009 Landgraf 700/49

OTHER PUBLICATIONS

Extended European Search Report issued Feb. 9, 2016 in Patent Application No. 12172397.7.

* cited by examiner

Fig. 1

Fig. 2

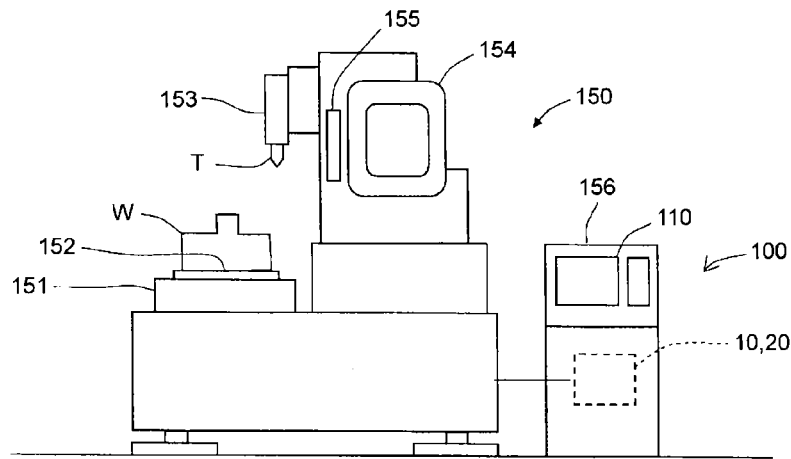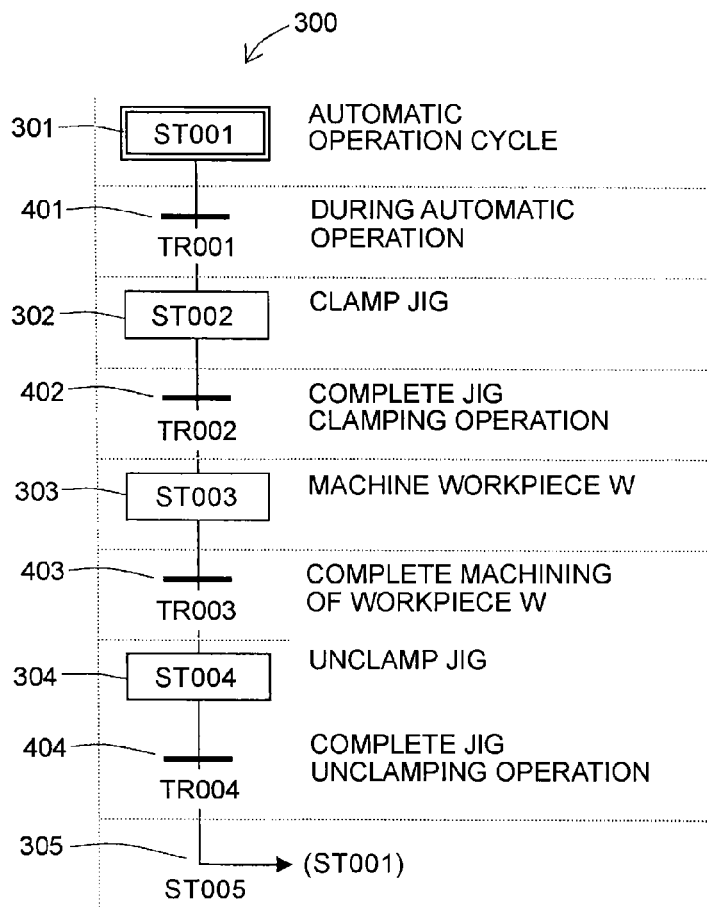|		
301	ST001	AUTOMATIC OPERATION CYCLE
401	TR001	DURING AUTOMATIC OPERATION
302	ST002	CLAMP JIG
402	TR002	COMPLETE JIG CLAMPING OPERATION
303	ST003	MACHINE WORKPIECE W
403	TR003	COMPLETE MACHINING OF WORKPIECE W
304	ST004	UNCLAMP JIG
404	TR004	COMPLETE JIG UNCLAMPING OPERATION
305	ST005	→ (ST001)

Fig. 3

310

311	ST001	UPPER FACE HEAD ASSEMBLING BOLT HOLE (M10×1.5) TAPPING
411		
312	ST002	ATC AND A90 TURN
412		
313	ST003	LEFT FACE BLOWBY COMMUNICATION HOLE BORING
413		
314	ST004	LEFT FACE OIL DROP COMMUNICATION HOLE BORING
414		
315	ST005	ATC
415		
316	ST006	LEFT FACE MACHINING REFERENCE SEAT SEAT MACHINING (φ30)
416		

Fig. 4

320

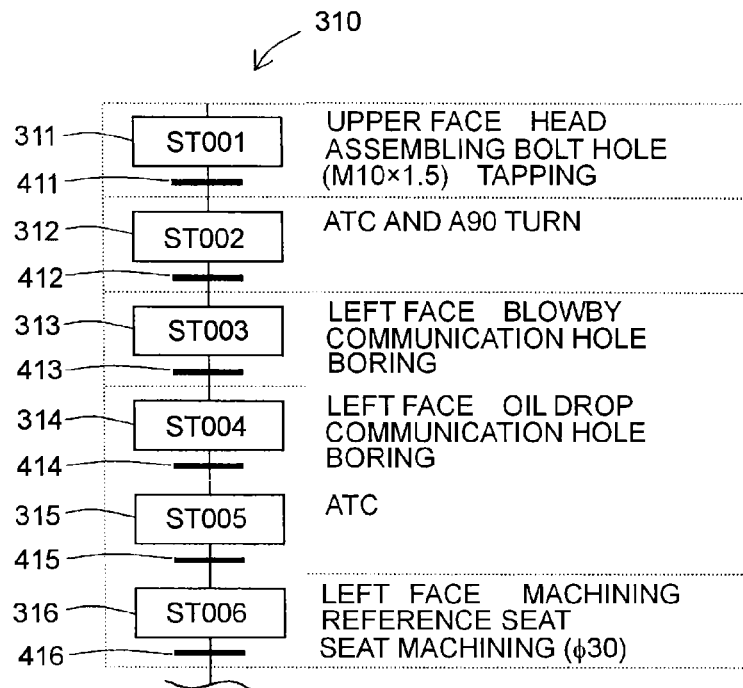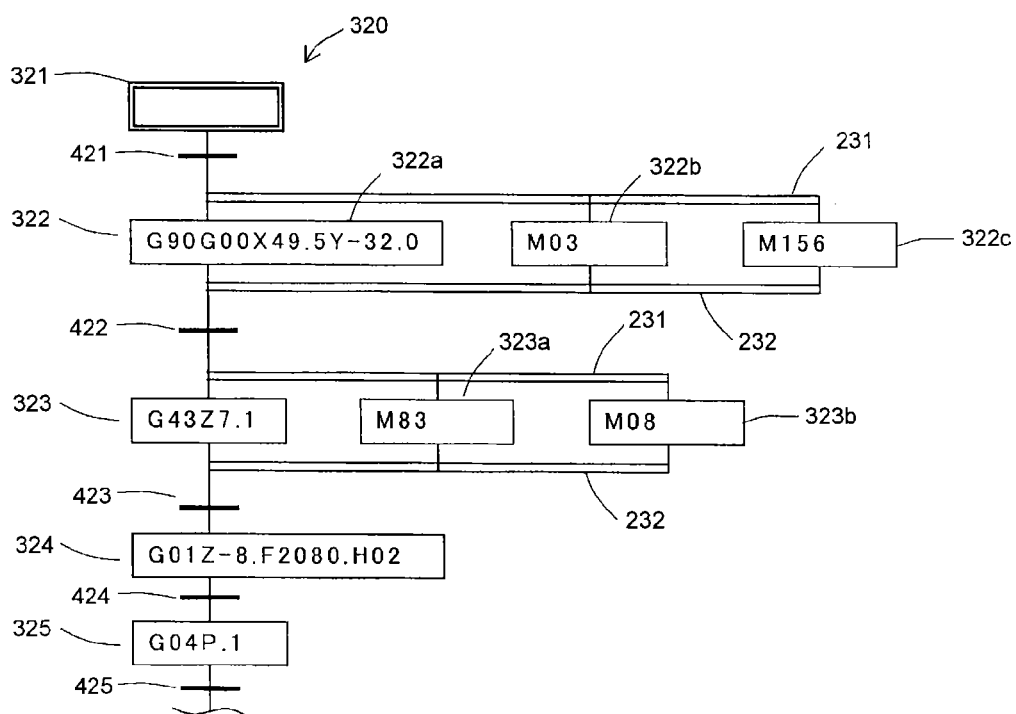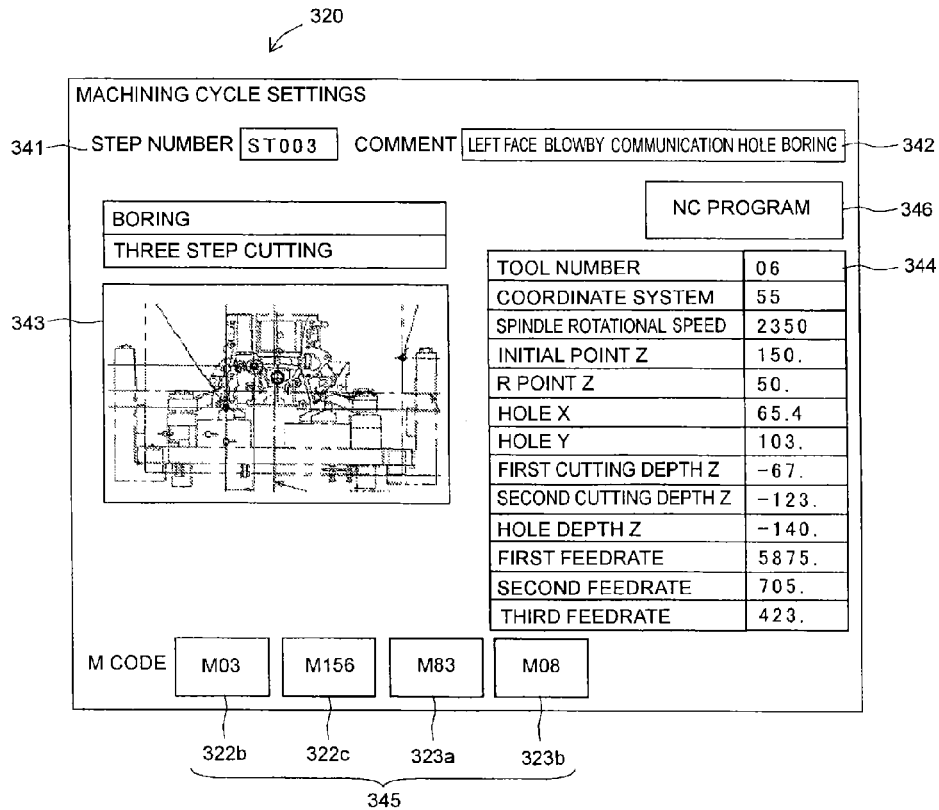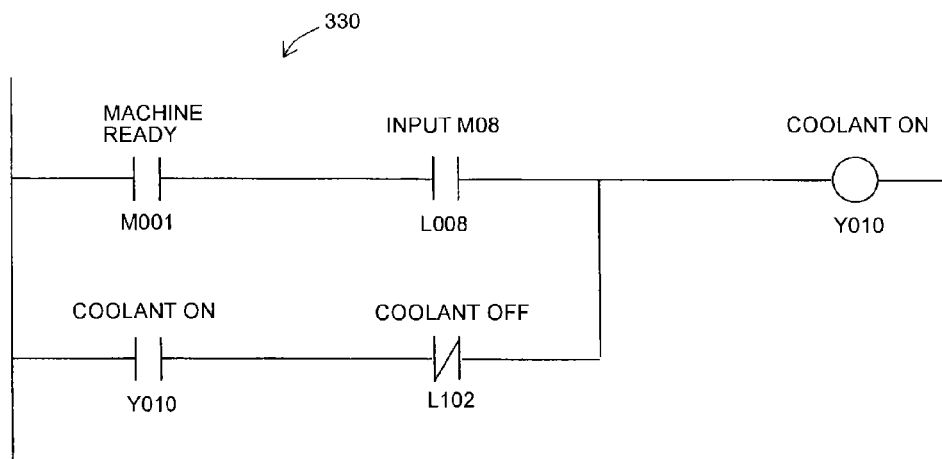|	
N0001:	M91
N0002:	G90G54(*$C002* COORDINATE SYSTEM *)G00X154. (*$C110* HOLE X*)Y− 119.(*$C111* HOLE Y*)M103S6000 (*$C003* SPINDLE SPEED *)F1200.(*$C004* FEED SPEED *)
223 ──▶ N0003:	G43Z250.(*$C112* INITIAL POINT Z*) H00(*$C000* TOOL NUMBER *)M03M156
N0004:	G00Z23135.(*$C113*R POINT Z*)
N0005:	G01Z23035.(*$C114* HOLE DEPTH (COORDINATE SYSTEM)Z*)G09
N0006:	G00Z23135.(*$C113*)

Fig. 5

320

321

421

322   322a   322b   231

| G90G00X49.5Y-32.0 | M03 | M156 | 322c |

422

231

323   323a

| G43Z7.1 | M83 | M08 | 323b |

232

423

324 | G01Z-8.F2080.H02 |

424

325 | G04P.1 |

425

232

Fig. 6

320

MACHINING CYCLE SETTINGS

341 — STEP NUMBER ST003   COMMENT LEFT FACE BLOWBY COMMUNICATION HOLE BORING — 342

BORING
THREE STEP CUTTING

NC PROGRAM — 346

343

TOOL NUMBER	06	— 344
COORDINATE SYSTEM	55	
SPINDLE ROTATIONAL SPEED	2350	
INITIAL POINT Z	150.	
R POINT Z	50.	
HOLE X	65.4	
HOLE Y	103.	
FIRST CUTTING DEPTH Z	-67.	
SECOND CUTTING DEPTH Z	-123.	
HOLE DEPTH Z	-140.	
FIRST FEEDRATE	5875.	
SECOND FEEDRATE	705.	
THIRD FEEDRATE	423.	

M CODE	M03	M156	M83	M08

322b   322c   323a   323b

345

Fig. 7

330

MACHINE
READY   INPUT M08   COOLANT ON
 ┤├   ┤├   ◯
M001   L008   Y010

COOLANT ON   COOLANT OFF
 ┤├   ┤/├
Y010   L102

Fig. 8

BLOCK EXECUTION SEQUENCE DISPLAY SYSTEM

INCORPORATION BY REFERENCE/RELATED APPLICATION

This application claims priority to Japanese Patent Application No. 2011-144523 filed on Jun. 29, 2011 the disclosure of which, including the specification, drawings and abstract, is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a block execution sequence display system for a numerical control device and a programmable controller for, for example, a machine tool.

2. Discussion of Background

In a machine tool, conventionally, a numerical control device is used to carry out axis control, and a programmable controller is used to control miscellaneous operations of, for example, miscellaneous equipments, other than the axis control. A program used in the numerical control device is a numerical control (NC) program written in a numerical control (NC) language. A program used in the programmable controller is a sequence program written in a program language, such as a ladder circuit diagram and a sequential function chart (SFC program). The ladder circuit diagram is a logical combination of signals by contacts and coils, and is suitable for visual recognition of a control circuit. The SFC program is written in a graphical program language that indicates a program in a plurality of divided steps in a flowchart form, and is suitable for representing the execution sequence and execution conditions of a program. The NC program and sequence program are programmed such that a series of operations are executed in a specified operation sequence by controlled axes and miscellaneous equipments that operate in association with each other.

A machine tool is often provided with a monitoring device as a peripheral device to, for example, monitor the operating states of such a numerical control device and a programmable controller, detect an abnormal or faulty portion, and debug a program. In a monitoring device for a programmable controller that uses a SFC program, as described in U.S. Pat. No. 5,426,730, the SFC program is graphically displayed on, for example, a display, and an active step or transition is displayed with, for example, a background color different from that of the other portions. Thus, an operator is able to visually recognize a currently executed portion of the SFC program easily. Therefore, for example, detection of an abnormal or faulty portion is facilitated.

However, in a machine tool in which control is executed by a combination of a numerical control device and a programmable controller, a control program is formed of a NC program and a sequence program that are different in type. Therefore, the execution sequence and execution status are not easily recognized with the use of a monitoring device. For example, the execution sequence of processes shown as steps in a SFC program is easily understood from the displayed information. However, with regard to processes of NC program operations included in a series of processes, the contents and execution sequence of a NC program are not easily visually recognized. The monitoring device is able to display a control circuit formed of, for example, a ladder circuit that is an action associated with a step when the step in the SFC program is selected. However, when a step associated with a NC program operation is

selected, a control circuit that starts up the NC program is displayed, and the contents of the NC program are not visually recognized. Therefore, in order to visually recognize the contents and execution sequence of a NC program, the NC program is separately retrieved, and the contents and execution sequence of the NC program are understood from the displayed NC language. Therefore, visually recognizing the contents and execution sequence of a NC program takes time and effort and requires knowledge about NC language.

In order to, for example, detect an abnormal or faulty portion or debug a program, the contents of a sequence program need to be checked from a NC program in some cases. For example, a command for miscellaneous equipment, written within a NC program and called an M code command, corresponds to an input condition for a control circuit for the miscellaneous equipment. The entity of the control circuit for the miscellaneous equipment is present in a program portion formed of, for example, a ladder circuit diagram that differs from the SFC program within the sequence program. Therefore, in order to check the contents of the sequence program that corresponds to the M code command from the NC program, the program portion formed of, for example, the ladder circuit diagram needs to be separately retrieved and the control circuit for the miscellaneous equipment, which corresponds to the M code command, needs to be found from the displayed circuit. This is not easy. In a situation where a trouble occurs in a machine tool and the cause of the trouble has to be found as soon as possible, if a lot of time is consumed to find a stop point of the NC program and a control circuit, a manufacturing line stops for a long time.

SUMMARY OF THE INVENTION

The invention provides a block execution sequence display system that is able to structurally and visually represent the entirety of a control program formed of a sequence program and a NC program to allow easy recognition of the execution sequence and execution status of the control program.

According to a feature of an example of the invention, a block execution sequence array in which sequence functional blocks of a sequence program and a NC program execution block are arranged in an execution sequence are displayed on a display device by block execution sequence array display means.

According to another feature of an example of the invention, operations of a NC program are displayed as a NC functional block execution sequence array, and each of the NC functional blocks of the NC functional block execution sequence array is displayed as a NC block execution sequence array. Thus, it is possible to represent the NC program as a hierarchical structure.

According to a further feature of an example of the invention, sequence functional blocks included in each of the NC functional blocks are displayed on the display device.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and further objects, features and advantages of the invention will become apparent from the following description of example embodiment with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. **1** is a block diagram that shows the configuration of a block execution sequence display system according to an embodiment of the invention;

FIG. **2** is a schematic view of a machine tool to which the block execution sequence display system according to the embodiment of the invention is applied;

FIG. **3** is an example of a block execution sequence array displayed by the block execution sequence display system according to the embodiment of the invention;

FIG. **4** is an example of a NC functional block execution sequence array displayed by the block execution sequence display system according to the embodiment of the invention;

FIG. **5** is an example of the list form of a NC block execution sequence array displayed by the block execution sequence display system according to the embodiment of the invention;

FIG. **6** is an example of the NC block execution sequence array of FIG. **5**, displayed in a SFC program form;

FIG. **7** is an example of the NC block execution sequence array of FIG. **5**, displayed in a dialog form; and

FIG. **8** is an example of a control circuit displayed by the block execution sequence display system according to the embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Hereinafter, an embodiment of the invention will be described with reference to the accompanying drawings.

The configuration of a block execution sequence display system **100** according to the present embodiment will be described. As shown in FIG. **1**, in a programmable controller **10**, a program memory **13**, a RAM **14**, a ROM **15**, an I/O control circuit **17**, a signal input/output interface **18** and a communication interface **19** are connected to each other via an internal bus **12** of a CPU **11**.

In a numerical control device **20**, a program memory **23**, a RAM **24**, a ROM **25**, a servo interface **27**, a signal input/output interface **28** and a communication interface **29** are connected to each other via an internal bus **22** of a CPU **21**.

A display unit **110** is formed of an LCD **121** and a touch panel **122**. The touch panel **122** is formed of a transparent electrode plate that covers the LCD **121**.

In the block execution sequence display system **100**, a RAM **114**, a ROM **115**, a display unit interface **118** and a communication interface **119** are connected to each other via an internal bus **112** of a CPU **111**.

The programmable controller **10** and the block execution sequence display system **100** are connected to each other via the respective communication interfaces **19**, **119**. Similarly, the numerical control device **20** and the block execution sequence display system **100** are connected to each other via the respective communication interfaces **29**, **119**. The programmable controller **10** and the numerical control device **20** are connected to each other via the respective signal input/output interfaces **18**, **28**.

A machine tool **150** that is a control target includes miscellaneous equipments **41**, **42**, **43** via the I/O control circuit **17** of the programmable controller **10**. In addition, the machine tool **150** includes motors **31**, **32**, **33**, **34** for respective controlled axes via the servo interface **27** of the numerical control device **20**.

The ROM **15** of the programmable controller **10** stores a sequence control unit **15a** and a sequence analyzing unit **15b** that are included in a system program. The RAM **14** has a working memory **14a** that is used when the system program

executes a sequence program **13a**. The program memory **13** stores the sequence program **13a**. The sequence program **13a** is formed of a SFC program for controlling the operation of the machine tool **150** and a ladder circuit diagram for controlling the miscellaneous equipments **41**, **42**, **43**. The system program is executed by the CPU **11** to control the entirety of the programmable controller **10**.

The ROM **25** of the numerical control device **20** stores a NC program analyzing unit **25a** and a NC control unit **25b** that are included in a system program. The RAM **24** has a working memory **24a** that is used when the system program executes a NC program **23a**. The program memory **23** stores the NC program **23a** written in a NC language for controlling the axis operation of the machine tool **150**. The system program is executed by the CPU **21** to control the entirety of the numerical control device **20**.

The ROM **115** of the block execution sequence display system **100** stores block execution sequence array display means **116a**, control circuit display means **116b**, NC functional block execution sequence display means **116c**, executing NC functional block display means **116d**, and NC block execution sequence display means **116e** that are all included in a system program **116**. The RAM **114** has a working memory **114a** that is used when the system program **116** executes the above display means **116a** to **116e**. The system program is executed by the CPU **111** to control the entirety of the block execution sequence display system **100**, and the above display means **116a** to **116e** are called upon operator's operation as needed. The above display means **116a** to **116e** display information on the display unit **110** via the display unit interface **118**.

Next, an example in which the present embodiment is applied to a machine tool **150** will be described. As shown in FIG. **2**, the machine tool **150** is a so-called machining center that has a table **151** and a spindle head **153**. A tool T is mountable on the spindle head **153**. Drive motors are connected to respective axis portions, and are controlled by the numerical control device **20**. A jig clamp device (not shown) and a coolant supply unit (not shown) are provided at the front face portion. The jig clamp device is used to fix a workpiece W on a pallet. A tool magazine **154** and an automatic tool changer (ATC) **155** are provided at the side face portion. The programmable controller **10**, the numerical control device **20** and the block execution sequence display system **100** are stored in a control box **156**, and are connected to the axis motors and miscellaneous equipments of the machine tool **150** via an interface. In addition, the display unit **110** is provided on the front face of the control box **156**. The coolant supply unit and the ATC **155** correspond to the miscellaneous equipments. The operations of the coolant supply unit and ATC **155** are controlled according to M code commands from a NC program.

Next, the operation of the block execution sequence display system **100** according to the present embodiment will be described. The overall control over the machine tool **150** is executed according to the SFC program of the sequence program **13a** stored in the program memory **13** of the programmable controller **10**. The SFC program is basically formed of a plurality of steps that represent control procedure, links that connect these steps to each other and transitions that represent conditions of transition from one step to the next step. A workpiece W is machined according to the NC program **23a** that is prepared for each workpiece W and that is stored in the program memory **23** of the numerical control device **20**. The NC program **23a** is started from one of the steps of the SFC program. The miscellaneous equipments are controlled according to the ladder

circuit diagram of the sequence program **13***a* stored in the program memory **13** of the programmable controller **10**. Commands for the miscellaneous equipments may be issued from either one of the sequence program **13***a* and the NC program **23***a*. Note that the sequence program **13***a* and the NC program **23***a* are created by respective creating devices, or the like.

The NC program creating device refers to a machining drawing for a workpiece W and sets machining condition parameters on the basis of a portion of the workpiece W to be machined and the type of machining. Thus, the NC program creating device is able to create blocks of the corresponding NC program. The thus created blocks of the NC program for each portion to be machined and each type of machining are called NC functional blocks. The entirety of the thus created NC program **23***a* is configured such that NC functional blocks are arranged in an execution sequence and each of the NC functional blocks includes successive NC blocks corresponding to an operation.

The SFC program shown in FIG. **3** is the SFC program of an automatic operation cycle executed when the machine tool **150** performs automatic operation to machine a workpiece W. The SFC program is started from the first step ST**001**. Step ST**001** is called initial step, and indicates the start point of the program. Step ST**002** is linked to step ST**001**, and is sequentially linked to step ST**003**, step ST**004** and step **305**. In addition, transition TR**001**, transition TR**002**, transition TR**003** and transition TR**004** are arranged between the consecutive steps. Although not shown in the drawing, step **305** corresponds to ST**005** and is called jump step. The jump step indicates that an execution point of the program is jumped to a specified step.

The SFC program is started from the initial step ST**001**, and performs jig clamping to clamp a workpiece W in the next step ST**002**. The clamping operation is controlled according to the sequence program **13***a*. The transition TR**002** is provided with a program that uses completion of jig clamping operation as a transition condition, so, when a jig clamping operation completion signal has been detected, the process proceeds to the next step ST**003**. In step ST**003**, machining of the workpiece is started according to the NC program for machining the workpiece W. The step ST**003** is provided with a program that starts the NC program **23***a* for machining the workpiece W. The comment of step ST**003** indicates that the NC program **23***a* is used to machine the workpiece W.

As shown in FIG. **1**, in the numerical control device **20**, when the NC program **23***a* for machining the workpiece W is started from the programmable controller **10**, the NC program **23***a* for machining the workpiece W is acquired from the program memory **23** and transferred to the NC program analyzing unit **25***a*. The NC program analyzing unit **25***a* analyzes the description written in the NC language, and transfers the analysis result to the NC control unit **25***b*. The NC control unit **25***b* executes axis control and device control in accordance with the analysis result. Axis commands are output to the respective axis motors **31**, **32**, **33** and spindle motor **34** via the servo interface **27**. M code commands for the respective miscellaneous equipments **41**, **42**, **43** are transmitted to the programmable controller **10** via the signal input/output interface **28**. Then, the programmable controller **10** operates the miscellaneous equipments **41**, **42**, **43** via the I/O control circuit **17** on the basis of the results processed by the control circuits using the M code commands, acquired via the signal input/output interface **18**, as input conditions.

Then, the transition TR**003** in FIG. **3** is provided with a program that uses completion of machining of the workpiece

W as a transition condition, so, when a machining completion signal has been detected, the process proceeds to the next step ST**004**. In step ST**004**, jig unclamping is performed. The transition TR**004** is provided with a program that uses completion of jig unclamping operation as a transition condition, so, when a jig unclamping operation completion signal has been detected, the process proceeds to the next step **305** (that corresponds to step ST**005**). In step ST**005**, the execution point of the program is jumped to the first step ST**001** that is the specified jump step. The SFC program of which the execution point of the program has been returned to the first step ST**001** repeats the above-described operations. Thus, the automatic operation cycle for machining a workpiece W is successively carried out.

In the block execution sequence display system **100**, the execution status of the above automatic operation cycle is displayed on the display unit **110**. The block execution sequence array display means **116***a* acquires the SFC program for automatic operation cycle from the programmable controller **10** via the communication interfaces **19**, **119**. Then, sequence functional blocks and a NC program execution block are arranged in a vertical line in an execution sequence into the form of a block execution sequence array **300**, and then displayed on the display unit **110**. Thus, the block execution sequence array **300** is displayed as shown in FIG. **3**. In the block execution sequence array **300**, the operations of the sequence program **13***a* and the operations executed according to the NC program **23***a* each are set as a single block, and the blocks are displayed in an array in an execution sequence of operations without distinguishing the sequence program **13***a* and the NC program **23***a* from each other. Therefore, it is possible to easily recognize the outline and execution sequence of the operations of the machine tool **150**. The block execution sequence array **300** is in the same form as the so-called SFC program of the sequence program **13***a*. During execution of the automatic operation cycle, in the block execution sequence array **300**, for example, the background color of a block that is currently executed is made different from the background color of the other blocks on the display so that the block that is currently executed is distinguishable from the other blocks. Thus, even when a machine trouble, or the like, occurs during execution of the automatic operation cycle and execution of the automatic operation cycle stops, it is possible to easily acquire the block at which the execution of the automatic operation cycle is stopped.

The block execution sequence array **300** is displayed on the display unit **110** by the block execution sequence array display means **116***a*. When an operator touches a step in the block execution sequence array **300** through the touch panel **122**, which may function as selecting means, the contents of the step are displayed. How to display the contents of a step varies depending on whether the selected step is a sequence functional block or a NC program execution block.

For example, when step ST**002** that is a sequence functional block is selected, the system program **116** calls the control circuit display means **116***b*. The control circuit display means **116***b* acquires the ladder circuit diagram of the sequence program **13***a* from the programmable controller **10** via the communication interfaces **19**, **119**. Then, a control circuit corresponding to step ST**002** is retrieved from the ladder circuit diagram, and the retrieved control circuit is displayed on the display unit **110**.

When step ST**003** that is a NC program execution block is selected, the system program **116** calls the NC functional block execution sequence display means **116***c*. The NC functional block execution sequence display means **116***c*

acquires the NC program **23***a* that corresponds to machining of the workpiece W, written in the comment of step ST**003**, from the numerical control device **20** via the communication interfaces **29**, **119**. The NC program **23***a* is created by the above-described NC program creating device, so the NC program **23***a* is configured such that NC functional blocks for respective portions to be machined and types of machining are arranged in an execution sequence. Then, the NC functional blocks are arranged in a vertical line in an execution sequence into the form of a NC functional block execution sequence array **310**, and then displayed on the display unit **110**. Thus, the NC functional block execution sequence array **310** as shown in FIG. **4** is displayed. In the NC functional block execution sequence array **310**, a NC functional block for each portion to be machined and each type of machining is set as one block and then the NC functional blocks are arranged and displayed in an operation execution sequence. Therefore, the outline and operation sequence of NC program operations are easily recognized.

Note that transitions **411** to **416** are provided so that the form of the NC program is in agreement with the form of the SFC program of the sequence program **13***a*, and represent completion of NC functional blocks, not program elements. During execution of the NC program **23***a*, for example, the executing NC functional block display means **116***d* makes the background color of a currently executed NC functional block different from the background color of the other blocks so that the currently executed NC functional block is distinguishable from the other blocks. Thus, even when a machine trouble, or the like, occurs during execution of the NC program **23***a* and execution of the NC program **23***a* stops, it is possible to easily acquire the NC functional block at which the execution of the NC program **23***a* stops.

The NC functional block execution sequence array **310** is displayed on the display unit **110** by the NC functional block execution sequence array display means **116***a*. When the operator touches a step of a NC functional block in the NC functional block execution sequence array **310** through the touch panel **122**, which may function as the selecting means, the system program **116** calls the NC block execution sequence array display means **116***e* to display a NC block execution sequence array **320** of that step. For example, when step ST**001** is selected, the NC block execution sequence array display means **116***e* acquires the NC functional block associated with step ST**001** from the NC program **23***a* of O number (O0010). Then, as shown in FIG. **5**, the NC block execution sequence array display means **116***e* displays the NC block execution sequence array **320** in a list form on the display unit **110**. In the NC block execution sequence array **320** in a list form, NC blocks that correspond to the selected step are arranged in an execution sequence. Thus, the NC block execution sequence array **320** is displayed as shown in FIG. **5**. In the NC block execution sequence array **320**, a NC block is displayed as one block and NC blocks are displayed in an array in an execution sequence of operations. Therefore, the outline and operation sequence of the operations of the NC program **23***a* are easily recognized. Each NC block has numerical control information and a sequence functional block. The numerical control information is formed of an N number and a command written in the NC language. The NC program **23***a* is executed in block unit at the same time.

In addition, during execution of the NC program **23***a*, the NC block execution sequence array display means **116***e* displays a currently executing mark **223** at, for example, an N number portion so that a currently executed NC block is distinguishable from the other blocks. Thus, even when a

machine trouble, or the like, occurs during execution of the NC program **23***a* and execution of the NC program **23***a* stops, it is possible to easily acquire NC block at which execution of the NC program **23***a* stops.

Furthermore, the NC block execution sequence array display means **116***e* is also able to display the NC block execution sequence array **320** in the SFC program form of the sequence program **13***a* as in the case of the block execution sequence array **300**. The NC block execution sequence array display means **116***e* arranges the NC language commands of NC blocks in a vertical direction in an execution sequence, and displays the numerical control information and sequence functional block of each NC language command in parallel with each other as separate blocks. Thus, the NC block execution sequence array **320** is displayed as shown in FIG. **6**. The blocks that are parallel to each other are provided with upper double lines and lower double lines that indicate a parallel branch **231** and a parallel join **232**, respectively, so that the form of the NC program is in agreement with the SFC program form of the sequence program **13***a*. Note that these double lines are not program elements. Transitions **421** to **425** are also provided so that the form of the NC program is in agreement with the SFC program form of the sequence program **13***a*. The transitions **421** to **425** represent completion of NC blocks, not program elements.

In addition, during execution of the NC program **23***a*, the above-described NC block execution sequence array display means **116***e*, for example, makes the background color of a currently executed block different from the background color of the other blocks so that the currently executed block is distinguishable from the other blocks in the SFC program form. Thus, even when a machine trouble, or the like, occurs during execution of the NC program **23***a* and execution of the NC program **23***a* stops, it is possible to easily acquire the NC block at which the NC program **23***a* stops. Furthermore, numerical control information and sequence functional blocks are displayed separately, so it is possible to easily recognize the execution statuses for M code commands.

In addition, the NC block execution sequence array display means **116***e* is also able to display the NC block execution sequence array **320** in a dialog screen form. The NC block execution sequence array display means **116***e* acquires parameters **344** and a workpiece machining drawing **343** from a database. The parameters **344** indicate machining conditions that correspond to a NC functional block. The workpiece machining drawing **343** corresponds to the NC functional block. Furthermore, a sequence functional block **345** formed of M code commands that correspond to miscellaneous equipments used in the NC functional block is acquired. Then, a dialog screen in which the parameters **344**, the workpiece machining drawing **343** and the sequence functional block are arranged is displayed. Thus, the dialog screen of the NC block execution sequence array **320** is displayed as shown in FIG. **7**. With this configuration, the parameters **344** of the machining conditions that correspond to the NC functional block are seen while the workpiece machining drawing **343** is referred to. The dialog screen is similar to the screen for creating an intended NC functional block in the above-described NC program creating device.

In addition, when an operator touches a NC program button **346** provided on the dialog screen through the touch panel **122**, which may function as the selecting means, the NC block execution sequence array **320** (FIG. **5**) in a list form, in which NC blocks that correspond to the NC functional block are arranged in an execution sequence, or

the NC block execution sequence array **320** (FIG. **6**) in a SFC program form is displayed on the display unit **110**.

In addition, during execution of the NC program **23***a*, the above-described NC block execution sequence array display means **116***e*, for example, makes the background color of a currently executed block different from the background color of the other blocks so that the currently executed block is distinguishable from the other blocks on the dialogue screen. Thus, it is possible to easily acquire the contents of machining of the NC functional block. Furthermore, sequence functional blocks are separately displayed, so it is possible to easily recognize the execution statuses for M code commands.

The NC block execution sequence array display means **116***e* displays the above-described NC block execution sequence array **320** in a SFC program form (FIG. **6**) and in a dialog form (FIG. **7**). When the operator touches a sequence functional block in the NC block execution sequence array **320** through the touch panel **122**, which may function as the selecting means, the system program **116** calls the control circuit display means **116***b*. For example, in the case where a machine trouble regarding a miscellaneous equipment occurs during execution of the NC program **23***a* and the execution of the NC program **23***a* stops, when the sequence functional block of the M code command (M**08**), displayed in the SFC program form (FIG. **6**) and dialog form (FIG. **7**) of the NC block execution sequence array **320**, is selected, the control circuit display means **116***b* acquires a ladder circuit diagram from the programmable controller **10** via the communication interfaces **19**, **119**. Then, the control circuit that uses the M**08** command as an input condition is retrieved from the ladder circuit diagram, and the retrieved control circuit **330** is displayed on the display unit **110**. Thus, the control circuit **330** is displayed. By checking the control circuit **330**, it is possible to easily recognize the execution status of the miscellaneous equipment.

Note that, in the present embodiment, the touch panel **122** is used as the selecting means of the block execution sequence display system **100**; instead, a mouse, a keyboard, or the like, may be used.

What is claimed is:

1. A block execution sequence display system, comprising:

a machine tool that includes a plurality of movable members that are configured to be movable through numerical control and a plurality of miscellaneous equipments that are operated through sequence control;

a programmable controller that executes a sequence program in which control circuits respectively included in a plurality of sequence functional blocks that respectively represent operations of the plurality of miscellaneous equipments are arranged in an operation sequence;

a numerical control device that executes a numerical control (NC) program in which NC blocks are arranged in an execution sequence, each NC block including at least one of numerical control information for moving the corresponding movable member through numerical control and the sequence functional block to be executed;

a first display image generator that displays a block execution sequence array in which the plurality of sequence functional blocks and a NC program execution block that represents execution of the NC program are arranged serially in an execution sequence, and a plurality of transition blocks are located between each sequence functional block and NC execution block on a display device, wherein the transition blocks use completion of the respective functional block and NC program block as a transition condition;

a selection device that receives selection of one of display of the plurality of sequence functional blocks and display of the NC program execution block, the plurality of sequence functional blocks and the NC program execution block being included in the block execution sequence array displayed, on the display device;

a second display image generator that, when the NC program is created so as to include a plurality of divided NC functional blocks each including a plurality of the successive NC blocks that correspond to a series of associated operations and the NC program execution block is selected by the selection device, displays a NC functional block execution sequence array in which the plurality of NC functional blocks are arranged in an execution sequence in the NC program, on the display device; and

a third display image generator that, when one of the NC functional blocks is selected by the selection device from the NC functional block execution sequence array displayed on the display device, displays a NC block execution sequence array, in which a plurality of the NC blocks included in the one of the NC functional blocks are arranged in an execution sequence, on the display device,

wherein

the third display image generator separately displays sequence functional block corresponding to the one of the NC functional blocks, selected by the selection device, on the display device,

the third display image generator displays the numerical control information and the sequence functional block that are included in each of the NC blocks in the NC block execution sequence array in parallel with each other, and

each numerical control information and each sequence functional block includes only one piece of control information.

2. The block execution sequence display system according to claim **1**, wherein the first display image generator displays a block, currently executed in the machine tool, among the plurality of sequence functional blocks and the NC program execution block on the block execution sequence array such that the currently executed block is distinguishable from the other blocks.

3. The block execution sequence display system according to claim **1**, wherein the second display image generator displays one of the NC functional blocks, currently executed in the machine tool, on the NC functional block execution sequence array such that the currently executed NC functional block is distinguishable from the other NC functional blocks.

4. The block execution sequence display system according to claim **1**, wherein the third display image generator includes a fourth display image generator that displays one of the NC blocks, currently executed in the machine tool, in the NC block execution sequence array such that the currently executed NC block is distinguishable from the other NC blocks.

5. The block execution sequence display system according to claim **1**, further comprising:

a fifth display image generator that, when one of the sequence functional blocks is selected by the selection device from the block execution sequence array displayed on the display device, displays the control circuit, included in the one of the sequence functional blocks, on the display device.

* * * * *